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ABSTRACT

Tests of spatial ability that were designed to minimize the effects of sociocultural expectations on performance were administered to adults of both sexes. The tests examined spatial problem-solving, spatial memory, and psychomotor spatial performance, as measured by three "throwing tasks." Thirty-four male and 34 female university students (aged 18-38 years) were the subjects. With the exception of one task (throwing a ball overhand, in which the males' scores were significantly higher than those of the females), no sex differences in performance were observed. The results indicate that performance on tests of spatial abilities must be regarded as a dynamic function of the interaction of sex, task demands, and task format, rather than as a static function of any of these factors alone. (Author/TJH).

"Sex Differences" in Spatial Abilities Depend on Task Factors

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Abstract

Tests of spatial ability which were designed to minimize the effects of sociocultural expectations on performance were administered to adults of both sexes. The tests examined spatial problem-solving, spatial memory, and psychomotor spatial performance, as measured by three "throwing tasks." With the exception of one throwing task (throwing a ball overhand), no sex differences in performance were observed. The results indicated that performance on tests of spatial abilities must be regarded as a dynamic function of the interaction of sex, task demands and task format, rather than as a static function of any of these alone.

"Sex Differences" in Spatial Abilities Depend on Task Factors

The assertion that the spatial abilities of males are superior to those of females (Harris, 1978; Maccoby & Jacklin, 1974; Porteus, 1965; Sanders & Soares, 1986) has recently been challenged (e.g., Caplan et al., 1985). Sex differences in spatial performance are usually small (Kimball, 1981; Plant, Southern & Jacklin, 1977), account for little variance (Hyde, 1981), and are not consistently found across studies (e.g., Fairweather, 1976; Gainer, 1962; Havighurst & Breese, 1947; Koch, 1954). Given the conflict in the literature on these issues, a reasonable hypothesis is that sex differences in spatial abilities are task dependent, and that sociocultural expectations may play a role in whether or not such differences are observed. We set out to test this hypothesis, using tasks designed to minimize the impact of sociocultural expectations on performance. Spatial problem-solving, spatial memory, and space-related psychomotor performance were measured.

Method

Research participants

Thirty-four men (age range 18-34 years) and thirty-four women (age range 18-38 years) were recruited through psychology classes at the University of Colorado. There were no differences between the female and male respondents in distribution of ages, college majors, or potentially relevant work or sports experience.

<u>Materials and procedures</u>

<u>Spatial problem solving</u>

Ten individuals of each sex were tested. Twenty-two items from the Shepard-Metzler Test of Mental Image Rotation were obtained and mounted on tachistoscope cards. Each item of the mental image rotation task consisted of two drawings of abstract objects (after Shepard & Metzler, 1971). The two drawings in each pair depicted either the same object or an object and its mirror image. The drawings were made from different perspectives. Of the twenty-two items, eleven depicted the same object and eleven depicted an object and its stereoisomer. The range of "difficulty" of the items, measured in terms of the main axis rotation for each item, was 20 to 170 degrees, with neither "hard" nor "easy" items being more prevalent. The items were presented one at a time on a Lafayette Instruments three-channel tachistoscope. Respondents were tested individually, and were told that the experiment was a test of how people think about objects. They were <u>not</u> informed that the experiment tested "spatial abilities," or that sex differences or similarities were a focus of the study. Each respondent was asked to "decide as quickly as possible whether the two pictures were the same or different." This required participants to rotate the objects mentally to an orientation at which this decision could be made

(Shepard & Metzler, 1971). As soon as the decision was made, the respondent pressed a switch which simultaneously shut off the tachistoscope and attached timer. Following this, the respondent reported the same/different decision. This decision, and the time required to reach it, was recorded for each item.

Memory for spatial locations

Fourteen individuals of each sex were tested. Two contrasting task contexts were employed, with seven male and seven female respondents randomly assigned to each. The two tasks were a "map" task, typical of representative laboratory paradigms (e.g., Light & Zelinski, 1983; Pezdek, 1983), and a "room" task, in which respondents were asked to remember the locations of previously-seen objects in a large room. The room and map were those previously employed in our laboratory (Sharps & Gollin, 1987).

The procedures of the room condition were conducted in a 7 x 9.75 m classroom at the University of Colorado. File cabinets, boards, lockers and carpets were organized into "structures," and were placed in such a way that the arrangement of the room would not resemble any environment with which respondents might be familiar. A 1/6 scale schematic map of this room was employed in the map condition.

Forty small, common objects were used as stimuli, the same in both the map and room conditions. Examples included a can opener, a flower, a baseball and a gum wrapper. A set of 40 white cardboard cards, each four cm square, was also prepared. Each card bore the name of one of the 40 stimulus objects. These were used to test spatial memory in both task conditions.

In the room condition, the forty objects were placed in randomly-determined locations in the room. Research participants were tested individually. Each participant was told that s/he would be shown a number of common objects, the locations of which were to be remembered. The experimenter then led the respondent on a circuitous tour of the room. At each of the 40 locations, the experimenter pointed to the object located there, named it, waited five seconds and continued on to the next object. At the conclusion of the tour, the respondent left the room. Meanwhile, all of the stimulus objects were removed. The respondent returned two minutes after leaving the room. He or she was then given the deck of forty cards, one card at a time, and was asked to place each card, face down, in the exact location where the item named on it had been placed.

The map condition was analogous to the room condition. The 40 objects were placed on the 1/6 scale schematic map, in positions that corresponded to their locations in the room. Research participants were given instructions analogous to those given in the room condition, and were then given a "tour" of the map. The experimenter pointed to the objects on the map in the same order used to point them out in the room, naming them and waiting five seconds between object presentations. At the conclusion of this "tour," the respondent left the room containing the map, the objects were removed from it, and the respondent returned to the map two minutes after having left it. A card placement task identical to that used in the room condition was then administered.

The number of correct card placements within 30 cm of the correct location of a given object in the room condition, or within 5 cm of the correct location on the map, was recorded. These criteria were to scale relative to one another. This type of measure of spatial memory has been shown to be adequate and redundant with other types of spatial memory measure (Light & Zelinski, 1983; Sharps & Gollin, 1986).

Psychomotor spatial performance: "throwing tasks"

Three psychomotor "throwing" tasks were employed. Ten male and ten female respondents participated in these tasks. The order of task administration was varied. The tasks were an "overhand," an "underhand," and a "spear" throw, and were intended to gauge the degree to which respondents could judge distances and object relations in space. The "spear" throw was included because the motions required were similar to those of the overhand throw, in which a practice effect in favor of males would be expected. It was felt that the spear itself was sufficiently unfamiliar that performance in the spear throw would be relatively unaffected by sex-differential practice effects. The order in which these tasks were administered was randomized across participants. Each individual was asked to throw a small rubber ball overhand and underhand through a 33 cm brass hoop from a distance of 3 m, and to throw a "spear" (made of a 130 x 2.54 cm dowell with a cloth padded head) overhand through the same hoop from the same distance. Each task required 10 throws of the ball or spear, and the number of times the projectile was thrown through the hoop was recorded for each participant.

Results

Means and standard deviations for all tasks are shown in Table 1. Analysis was accomplished by simple t-tests. Eight t-tests were required, which yielded an unacceptably high experiment-wise error rate of 33.66% at $p=.05$. All results were therefore also evaluated by means of a protected Tukey Honestly Significant Difference Procedure and a Student-Newman-Keuls procedure ($p<.05$ and $p<.01$), both of which confirmed the t-test findings. No significant differences were observed between male and female performance, with the exception of the overhand ball throw, in which male scores were significantly higher than female scores, $t(18)=3.56$, $p=.002$.

Discussion

The tasks employed assessed a wide variety of spatial abilities. The only task which produced a sex difference in performance was the overhand ball throw, a type of activity which is obviously more practiced by males than the other tasks employed. Given the probable effect of practice, and the finding that the other throwing tasks exhibited no sex differences, the significant effect of the overhand throwing test would appear to derive from sex sterotyping or from practice effects.

The results of our spatial memory tasks indicate very strongly that spatial memory performance is not influenced by the gender of the respondent. Our adaptation of the Shepard-Metzler task also produced no sex differences in spatial problem-solving. This would appear to contradict a rather large literature (e.g., Bouchard & McGee, 1977; Herman & Bruce, 1983; Sanders & Soares, 1986; Sanders, Soares, & D'Aquila, 1982; Vandenberg & Kuse, 1978; Wilson & Vandenberg, 1978; Yen, 1975). A number of factors may have combined to produce this difference in results. For example, many respondents in our laboratory spontaneously reported a feeling of intimidation or dismay on seeing the pages of multiple-choice items used in the standard test, the Vandenberg and Kuse (1978) version of the Shepard-Metzler test, but no one reported such feelings with our tachistoscopic presentation, in which only one item was presented at a time. The multiple-choice format of the standard test may also have influenced performance, as has been the case in other areas of testing and assessment (e.g., Frederiksen, 1986; Levine et al, 1970).

Other factors than task format may also influence the performance of female and male respondents. For example, Tapley & Bryden (1977) employed a tachistoscopic procedure very similar to the one employed here to present 100 Shepard-Metzler items to 20 female and 20 male participants. Males performed at a higher level than females. However, prior to item presentation, respondents were given a battery of tests of imagery and spatial abilities, including the Standardized Road-Map Test of Direction Sense (Money, Alexander, & Walker, 1965), an obviously "spatial" test which might have "primed" the later Shepard-Metzler performance of female and male respondents. It is also possible that the greater number of items may have played a role in the Tapley & Bryden study. Given the widelv differing results of Tapley and Bryden and of the present study, a systematic and complete exploration of the effects of task type on Shepard-Metzler mental image rotation should definitely be the subject of future research. However, whatever the underlying factors regarding this particular task, the present study indicates very strongly that whether or not one finds "sex differences" in mental image rotation or in other spatial abilities depends in large part upon how the experimental procedures are constructed and administered. Neither "sex differences" nor "spatial abilities" are fixed entities. Rather, the potential role played by gender in any given behavior derives from a variety of sociocultural and rearing factors as well as putative biological sources. "Spatial abilities" operate in a variety of contexts that are by no means homogeneous, as the breadth of the literature on spatial behavior indicates. Moreover, there is a dynamic relationship between the abilities that a given individual brings to a given spatial task, the way in which that task is structured, and whatever factors the individual's gender may entail. "Sex differences" may or may not be observed in any given paradigm, depending upon the specific configuration of these three sets of factors.

It has been asserted that it is "at least premature and indeed inappropriate to ask about sex differences in spatial ability" (Caplan et al., 1985). The present findings support this assertion, at least with respect to the search for global, pervasive differences due to gender. Neither "sex differences" nor "spatial abilities" can be viewed as isolated or static entities. Neither can be viewed as a process separate from the context in which it is investigated. A systematic analysis of context, task, gender and performance must be employed if the dynamic relationship of gender to behavior is to be adequately understood.

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Table 1

Mean Performance Scores and Standard Deviations of Male and Female Respondents

	Male		Female	
Mental Image Rotation Test				
	Mean	S.D.	Mean	S.D.
Decision Time (seconds):	5.03	2.66	6.46	3.15
Decision Score:	19.70	1.95	20.00	1.63
Spatial Memory Test				
	Male		Female	
	Mean	S.D.	Mean	S.D.
Map Score:	10.86	2.61	12.71	3.68
Room Score:	22.71	6.47	23.57	6.37
Psychomotor Tests				
	Male		Female	
	Mean	S.D.	Mean	S.D.
Pooled Throw Score:	16.70	3.97	11.20	5.16
Overhand Throw Score:	7.00	1.15	4.00	2.40
Underhand Throw Score:	5.60	1.89	4.50	2.22
"Spear" Throw Score:	4.10	2.42	2.70	1.63